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IMPOUNDING WATER IN A BAYOU TO CONTROL BREEDING OF MALARIA MOSQUITOES.

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INTRODUCTION.

Malaria is responsible for important losses in returns from agricultural crops in the Delta region of the lower Mississippi Valley. The disease is, as well, a great handicap to the further development and extension of agriculture in that region. The prevailing system of labor in the Delta is that of the negro tenant farmer, and it is among this class that the disease is highly prevalent, causing losses

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in time and in reduced efficiency of the plantation hands during the season of the year when the crops are most in need of attention.

The bayous or streams of the region are an important source of the Anopheles mosquitoes which convey malaria, and since the higher ridges offered by the bayou banks are the logical locations for the plantation roadways, the homes of the tenants are located along these banks. While control of the breeding of Anopheles in a bayou is but one factor in the ultimate control of the malaria mosquitoes in the Delta, it is an important factor, for these bayous offer a near-by source of Anopheles in locations on the plantations which are otherwise favorable in respect to distance from breeding areas of these mosquitoes.

Since the general topography of the Delta and the slight fall in the bed of the bayous do not permit drainage, the common practice in disposal of surplus surface water, it became necessary to devise some method of control, practical from the standpoint of plantation management, to prevent breeding of Anopheles in bayous. The Bureau of Entomology has demonstrated that the breeding of Anopheles mosquitoes can be controlled in a bayou by clearing the vegetation and impounding the water. The work was located on Hecla plantation at Mound, Madison Parish, northeastern Louisiana. This bulletin deals with the natural conditions of the bayou before the work was done and with the changed conditions brought about by the work, especially with reference to the breeding of mosquitoes. It also discusses the impounding of water in a bayou from the standpoint of plantation economy.

TOPOGRAPHY AND FORMATION OF THE REGION.

To gain an idea of the relation of the streams of this region to the surrounding topography, it is necessary to discuss in a very general manner the formation of the region. The soil is an alluvial deposit of considerable depth and the formation is characteristic of delta accumulations. There is a slight fall in the general direction of the main stream, the Mississippi River. This river in times past has followed an irregular, winding course through the Delta of its lower valley, often forming new channels. The old channels are marked by the ridges which are peculiar to the region. The bayous, or streams, of the region are in reality old spillways of the river when at flood, formed before the days of the protective levee system by the tendency of the river at stages of high water to break through its built-up banks and form new channels for the surplus water. Before the levees were built, the river and these bayous overflowed their banks at regular seasonal intervals. The heavier particles carried by the water in suspension were deposited first and in larger quantity. The finer particles were deposited in smaller amounts as one

proceeds from the banks of these streams to either side. The deposits from these overflows account for the ridges along the bayous and the ancient channels of the river. There is, therefore, a gradual fall from these ridges to the lands that lie on either side. These lower lands are extensive swamp areas in the basins of which are found permanent swamp "lakes" which are extremely shallow. The banks of the bayous are formed with a steep declivity toward their channels in contrast to the gradual slope toward the swamp areas that lie parallel to them. The region is further characterized by narrow, crescent-shaped lakes within well-defined banks of the old beds of the river, known as "ox-bows" or "cut-offs," formed where the action of the river has cut a new channel through the neck of one of its many horseshoe bends. The ends of these "cut-off" lakes are usually shallow, showing marshlike conditions, but the main body of water is open and comparatively deep. The bayous are not connected with these lakes except during periods of high water. The swamp lakes tend to drain into the bayous at points lower down in the courses of these streams.

FAVORABLE CONDITIONS FOR MOSQUITO DEVELOPMENT.

The swamp areas and the channels of the bayous are attended by a rank growth of vegetation consequent upon the fertile nature of the alluvial deposit and the prevalent moisture which, with the resulting sediment and vegetable débris, promotes an ideal environment for the development of certain species of mosquitoes under favorable climatic conditions. The situation becomes increasingly emphasized by reason of the imperfect drainage due to the slight fall of the land. Among the mosquitoes, Anopheles are found to thrive, and the disease which they convey is prevalent among the inhabitants of the region.

LOCATION OF CULTIVATED LANDS, ROADWAYS, AND DWELLINGS.

In the Delta the timbered lands are practically synonymous with the swamp areas. The open lands, or lands under cultivation, are confined to comparatively narrow strips along the ridges that form the banks of the river, the bayous, and the old courses of these streams. These lands are known as the "front" lands and from the nature of their deposits are sandy in character. The lands lying toward the swamp areas are known as the "back" lands and are a heavy clay, impervious to water, called "buckshot."

The roadways of the region follow the higher lands and, wherever practical, are carried along the bayou banks. The open land is cultivated under the negro tenant system, each tenant living upon the land assigned to him for cultivation. It is therefore logical to find the homes of the tenants on a roadway along the bayou where

one of these streams bounds or sections a property. The houses thus located are in the higher and more open portions of the plantation and usually at maximum distance from the timbered and swamp areas on either side. It is evident that such location of the habitations is favorable in respect to distance from the breeding areas of Anopheles mosquitoes, with the exception of those mosquitoes that originate in the bayou itself.

PROBLEM OF ANOPHELES CONTROL IN THE REGION.

Of course complete drainage of surface water is the logical method of Anopheles control where that method applies, but in the absence of a drainage outlet, and in the presence of surface water favorable for Anopheles breeding throughout the season, other means must be given local consideration. In any consideration of drainage in the Delta it is necessary to note that the streams of this region flow away from the river, that the slope of the land is from the bayou bank toward the swamp areas on either side, and that the fall in the bed of the bayou averages less than a foot to the mile. Under these conditions the question of drainage involves an extensive area; it is not a matter which the plantation owners can consider individually.

The idea of impounding water to suppress mosquito breeding is rather foreign to the general conception of the effect of impounded water upon mosquito production. The relation which impounded water will bear to mosquito production depends altogether upon the conditions under which the work is done and the changes brought about in comparison to the natural conditions. In the question of impounding water in a bayou we must consider the natural character of such a stream and the relation of the stream to the roadways of the plantation and the habitations of the people who cultivate the land. The bayou bank is the logical location for the houses of the tenants and it is important to control the breeding of Anopheles in this nearby source. The bayou under natural conditions favors mosquito production but under impounded conditions does not. The change in conditions is brought about by the preliminary clearing and by the provision for a permanent water level sufficiently high to suppress the growth of aquatic vegetation. Following these operations, the maintenance of a clean margin is all important.

BAYOU WALNUT AND THE ANOPHELES SURVEY.

The work of the Bureau of Entomology was done in a section of Bayou Walnut which quarters the southwest portion of Hecla plantation. This bayou runs a very irregular course from a point slightly north of Milikens Bend on the Mississippi River to Bayou Roundaway, joining the latter stream southwest of Tallulah. From the

View along channel, Bayou Walnut, natural conditions, showing overhanging vegetation. Note log and "floatage" on surface of water.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

FIG. 1.—View along channel, Bayou Walnut, natural conditions, showing overhanging vegetation and aquatic vegetation in bed. Surface of water in foreground covered with duckweed (*Lemna* spp.) and with aquatic plant, *Jussiaea diffusa*, in background.

FIG. 2.—View across Bayou Walnut, natural conditions, showing absence of overhanging vegetation, with aquatic grass, *Zizaniopsis miliacea*, in bed.

point of origin of the bayou to its junction with Roundaway, the distance in an air line is only 7½ miles. The bayou, however, travels a distance of over 31 miles. The section of Bayou Walnut in its course through Hecla plantation is shown in Figure 1. The average fall of the bayou in this section is 0.6 foot to the mile.

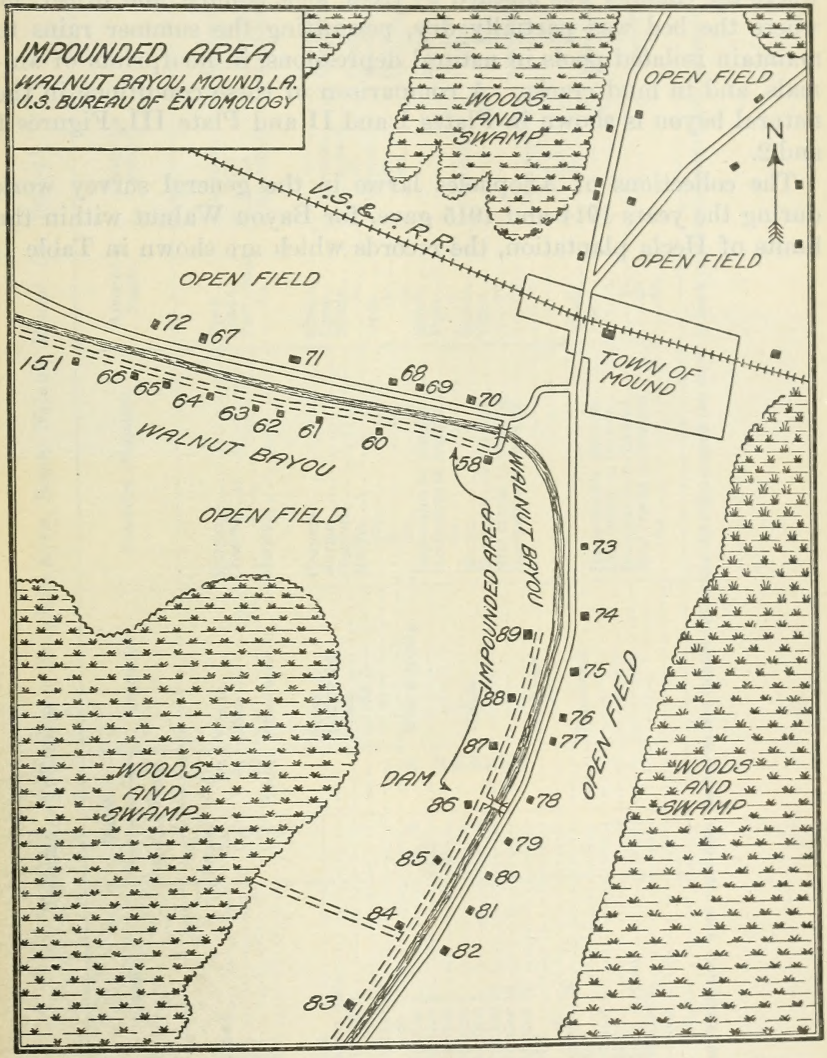

FIG. 1.—Map of section of Bayou Walnut near Mound, La., showing impounded area and surroundings.

During 1914 it was observed that under natural conditions there was practically no breeding of Anopheles in certain restricted sections of the bayou where open water occurred, where the bed was free of vegetation, and where the margins were clean. On the other

hand, breeding was found in those portions of the bayou where the margins were grass-grown or supported a growth of overhanging trees and vines; where the water surface was covered with the resulting vegetable débris or floatage; where the water was shallow enough to support the growth of aquatic vegetation in the bed of the stream; where the channel was blocked by trees, logs, stumps, and brush; or where the bed was partially dry, permitting the summer rains to maintain isolated pools in natural depressions, in hoofprints of animals, and in mud cracks. A comparison of these conditions in the natural bayou is shown in Plates I and II and Plate III, Figures 1 and 2.

The collections of Anopheles larvæ in the general survey work during the years 1914 and 1915 gave, for Bayou Walnut within the limits of Hecla plantation, the records which are shown in Table 1.

TABLE 1.—*Collections of Anopheles larvæ, Bayou Walnut, Mound, La., 1914–15.*

Date.	Record No.	Locality.	Water.		Vegetation.	Character of location.	Amount of Shade.	Gambusia present.	Species.
			Depth.	Temp.					
1914.			*Inches.*	°*F.*					
Aug. 10	4258	H74–75	1–5	104	Weeds	Margin	Open	Common	Species undetermined.
10	4259	H76	.5	84	Grass	Channel	Shade	do	Do.
11	4266	H77	5	89			Part shade	do	Quadrimaculatus.
22	4323	H73	3	90–94	Smartweed	Margin	do	Abundant	Quadrimaculatus, punctipennis.
1915.									
May 26	4701	H89			Grass	Channel	Shade	do	Crucians.
June 3	4712	Below dam			Duckweed	Margin	Open	Common	Quadrimaculatus.
8	4724	Station 9			Grass	Channel	Shade	Abundant	Do.
8	4725	do			do	Margin	do	do	Species undetermined.
9	4727	Station 15				do	Open	Common	Quadrimaculatus.
11	4729	do				do	do	do	Species undetermined.
July 6	4748	Station 4	3	90	Willow stump	do	do	do	Quadrimaculatus.
Aug. 3	4772	Station 2				Depression at margin	Shade		Do.
4	4774	Station 3		83		Hoofprints at margin	Open		Species undetermined.
5	4775	Station 4		84		do	do		Do.
5	4776	Station 5	2	88	Willow	Margin	Shade	Common	Do.
6	4783	Station 12		81–85		Hoofprints in channel	Open		Do.
6	4784	Station 13		80–90		Mud cracks in channel	do		Do.
18	4783–10	Station 12		81		Hoofprints in channel	do		Quadrimaculatus.
27	7306	H85			Duckweed			Common	Do.
28	7311	do			do			do	Do.
Sept. 1	7315	Station 10						do	Do.
18	7318	H85			Duckweed		Shade	do	Do.
Oct. 23	7355	Station 6				Hoofprints in channel	Open		Punctipennis.
27	7358	H79	2			Depression at margin	do		Do.
27	7357	Dam station				Hoofprints in channel	do		Do.
27	7359	Station 3				Mud cracks in channel	do		Quadrimaculatus, punctipennis.
29	7360	do				do	do		Do.

[1] The collections after this date were made after the bayou was cleared but before the rains caused the water to back up over the cleared area by reason of the dam.

These records indicate general breeding of Anopheles throughout the course of the stream under natural conditions. *Anopheles quadrimaculatus* Say is the common species taken, and *Anopheles punctipennis* Say is second in numbers. It is noted that one collection of *Anopheles crucians* Wied. was made. The undetermined collections represent the Anopheles larvæ which were collected but which were not reared to the adult stage.

For convenience of the survey, the section of the bayou to be cleared of all vegetation was divided into stations 100 yards in length. The distance covered in the experiment was 1,600 yards, nearly a mile. The plants collected from this section, before clearing, during July and August, 1915, are shown in Table 2. The plants listed in Table 2 are distributed according to their location and the depth of water in the bayou in Table 3. The plant determinations were made by the Bureau of Plant Industry of this department. The natural conditions in the bayou, including the vegetation, water levels, and other features, are shown in Plate III, Figure 3; Plate IV; and Plate V, Figure 1.

TABLE 2.—*Plants from Bayou Walnut, Mound, La., 1915.*

Species.	Common name.	Location.
Spirogyra sp	Algæ	Submerged.
Lemna valdiviana, Lemna gibba, Spirodela polyrhiza, and Wolffia columbiana	Duckweed	Floating on water.
Jussiaea diffusa	Primrose-willow	In water, roots in bed.
Zizaniopsis miliacea	Aquatic grass	Do.
Cephalanthus occidentalis	Buttonbush	In channel and along margin.
Salix nigra	Swamp willow	Along margin, overhanging.
Bignonia radicans	Trumpet creeper	Do.
Brunnichia cirrhosa	Buckwheat vine	Do.
Persicaria opelousana	Smartweed	Along margin.
Phytolacca americana	Pokeberry	Do.
Panicum colonum	Ditch grass	Do.
Asclepias perennis	Milkweed	Do.
Ampelopsis arborea	Peppervine	Do.
Belonging to family Euphorbiaceae	Spurge	Do.

TABLE 3.—*Vegetation and depth of water in Bayou Walnut, Mound, La., before impounding, July–August, 1915.*

Station.	Vegetation.			Depth of water in channel.
	Species.	Common name.	Location.	
Dam.	Lemna spp[1]	Duckweed	Floating on water	6 inches to 11 inches.
	Jussiaea diffusa	Primrose-willow	In water	
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Persicaria opelousana	Smartweed	Margin	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
	Euphorbiaceae	Spurge	Margin	

[1] The species of duckweed recorded under *Lemna* spp. in this list represent *Lemna valdiviana, L. gibba, Spirodela polyrhiza,* and *Wolffia columbiana.* Submerged algæ (Spirogyra) were common along the margins in some locations, but the submerged hornwort (Ceratophyllum) was not collected in this survey, though it is common in some other locations in the region.

FIG. 1.—View along edge of Bayou Walnut, natural conditions, showing open water in channel with grass-grown margin.

FIG. 2.—View along channel of Bayou Walnut, natural conditions, showing clean margin on opposite bank and vegetation along margin in immediate foreground.

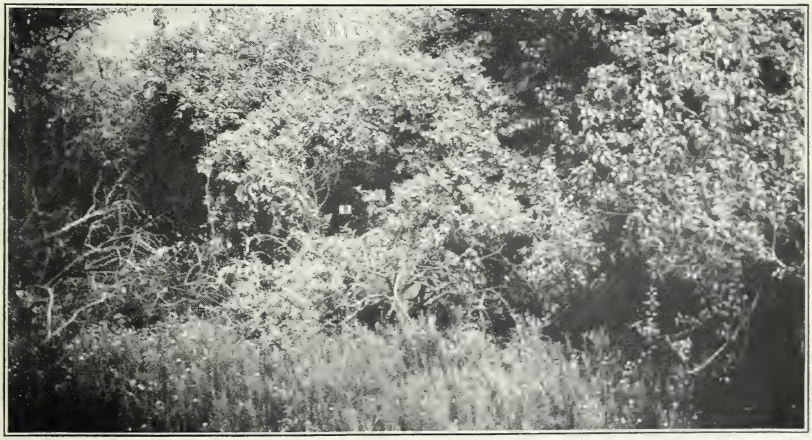

FIG. 3.—Looking across Bayou Walnut, 200 yards above site of dam, before clearing.

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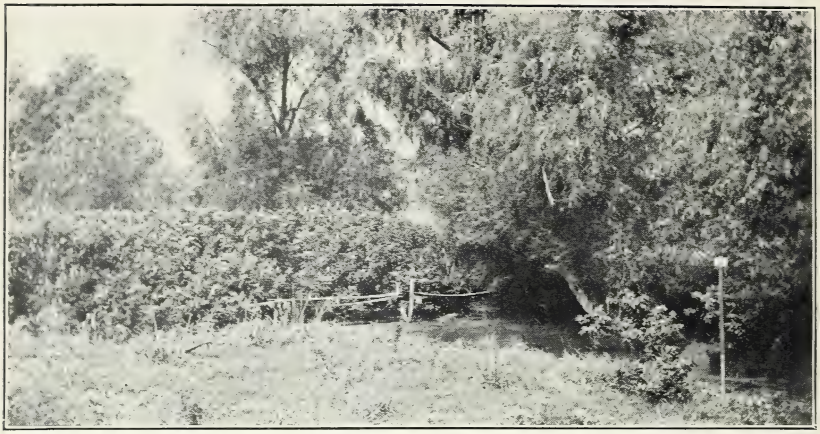


FIG. 1.—Looking down channel of Bayou Walnut, 300 yards above site of dam, before clearing.

FIG. 2.—Looking across Bayou Walnut, 500 yards above site of dam, before clearing.

FIG. 3.—Looking across Bayou Walnut, 900 yards above site of dam, before clearing.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

TABLE 3.—*Vegetation and depth of water in Bayou Walnut, Mound, La., before impounding, July–August, 1915*—Continued.

Station.	Vegetation.			Depth of water in channel.
	Species.	Common name.	Location.	
1	Lemna spp	Duckweed	Floating on water	3 inches to 1 foot 3 inches.
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
	Asclepias perennis	Milkweed	Margin	
	Phytolacca americana	Pokeberry	do	
	Brunnichia cirrhosa	Buckwheat vine	Margin, overhanging	
	Persicaria opelousana	Smartweed	Margin	
	Ampelopsis arbroea	Peppervine	do	
	Bignonia radicans	Trumpet-creeper	Margin, overhanging	
2	Lemna spp	Duckweed	Floating on water	3 inches to 1 foot.
	Jussiaea diffusa	Primrose-willow	In water	
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
	Asclepias perennis	Milkweed	Margin	
	Phytolacca americana	Pokeberry	do	
	Brunnichia cirrhosa	Buckwheat vine	Margin, overhanging	
	Persicaria opelousana	Smartweed	Margin	
	Bignonia radicans	Trumpet-creeper	Margin, overhanging	
3	Lemna spp	Duckweed	Floating on water	2 inches to 1 foot.
	Jussiaea diffusa	Primrose-willow	In water	
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
	Panicum colonum	Ditch grass	Margin	
	Persicaria opelousana	Smartweed	do	
	Asclepias perennis	Milkweed	do	
4	Lemna spp	Duckweed	Floating on water	9 inches.
	Jussiaea diffusa	Primrose-willow	In water	
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
5	Lemna spp	Duckweed	Floating on water	2 inches to 6 inches
	Jussiaea diffusa	Primrose-willow	In water	
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacaea	Aquatic grass	Bed, in water	
6	Lemna spp	Duckweed	Floating on water	6 inches.
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
7	Lemna spp	Duckweed	Floating on water	2 inches to 8 inches (one-third dry).
	Salix nigra	Swamp willow	Margin, overhanging	
	Zizaniopsis miliacea	Aquatic grass	Bed and margin	
8	Lemna spp	Duckweed	Floating on water	4 inches (two-thirds dry).
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Stumps at margin	
	Zizaniopsis miliacea	Aquatic grass	Bed and margin	
9	Lemna spp	Duckweed	Floating on water	3 inches.
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Stumps along margin	
	Zizaniopsis miliacea	Aquatic grass	Bed and margin	
10	Lemna spp	Duckweed	Floating on water	6 inches.
	Cephalanthus occidentalis.	Buttonbush	Bed and margin	
	Salix nigra	Swamp willow	Stumps along margin	
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
11	Salix nigra	Swamp willow	Margin	2 inches (one-third dry).
	Zizaniopsis miliacea	Aquatic grass	Bed, in water	
12	Salix nigra	Swamp willow	Trees in bed, stumps along margin.	Dry (except hoof-prints and mud cracks).
13	Salix nigra	do	do	Do.
14	Salix nigra	do	do	Dry, except small pool near bridge.
	Zizaniopsis miliacea	Aquatic grass	Margin	
15	Salix nigra	Swamp willow	Stumps along margin	Dry, except one small pool.

FISHES OF THE REGION.

A survey of the fishes of this region was made by the United States Bureau of Fisheries in cooperation with this work. This survey was intended to cover the distribution of the top minnow (*Gambusia affinis*) in this region; the possible presence of fishes other than this minnow that would be useful in mosquito destruction; the fishes valuable as food in the deeper and permanent areas of water; the survival of Gambusia in the impounded area in Bayou Walnut; and the possibility of establishing in the impounded area fishes that would be of value for food to the tenants on the plantation. This work was accomplished during 1916 and the early part of 1917. The fishes collected in Bayou Walnut under natural conditions are listed in Table 4. It is seen that *Gambusia affinis* is the prevalent species.

TABLE 4.—*List of fishes taken in five collections in the natural area, Bayou Walnut, Mound, La., 1916–17.*

Species.	Common name.	Number of collections.	Number of specimens.
Gambusia affinis	Top minnow	5	124
Dorosoma cepedianum	Hickory shad	1	20
Lepomis cyanellus	Green sunfish	1	20
Lepomis humilis	Sunfish	1	19
Lepomis pallidus	Blue-gill sunfish	1	4
Lepomis symmetricus	Sunfish	1	3
Pomoxis sp		1	3
Carpiodes sp		1	1

A point of special interest in connection with the natural conditions of the bayou is the fact that Gambusia is found in connection with general breeding of Anopheles. The breeding of these mosquitoes in the presence of comparatively large numbers of this minnow is accounted for by the protection afforded the mosquito larvæ by the aquatic and marginal vegetation and the vegetable débris upon the surface of the water. Further, the partially dry condition of the bayou at certain seasons provides isolated pools and water in hoofprints of animals and in mud cracks from rains, to which the fish do not have access.

A complete list of the fishes collected in this region, not including the impounded area in Bayou Walnut and the Mississippi River, is shown in Table 5.

TABLE 5.—*List of fishes taken in 38 collections from seasonal and permanent waters (exclusive of Mississippi River) in the vicinity of Mound, La., 1916–1917, by F. M. Barnes, United States Bureau of Fisheries.*

Species.	Common name.	Number of collections.	Number of specimens.
Gambusia affinis	Top minnow	27	2,410
Lepomis cyanellus	Green sunfish	16	151
Lepomis humilis	Sunfish	10	126
Lepomis megalotis	Sunfish	4	6
Lepomis pallidus	Blue-gill sunfish	3	9
Lepomis symmetricus	Sunfish	2	4
Lepomis ischyrus	Sunfish	1	1
Lepomis euryorus	Sunfish	2	13
Dorosoma cepedianum	Hickory shad	12	483
Notemigonus crysoleucas	Roach, shiner	11	582
Ameiurus nebulosus	Common bullhead	11	198
Ameiurus melas	Black bullhead	1	1
Pomoxis annularis	Crappie	10	836
Pomoxis sparoides	Calico bass	9	104
Chaenobryttus gulosus	Warmouth bass, "goggle-eye"	5	35
Signalosa atchafalayae	Shad	5	313
Aphredoderus sayanus	Pirate perch	4	20
Roccus chrysops	White bass	4	4
Hybopsis hyostomus (sp. ?)		4	20
Micropterus salmoides	Large-mouth black bass, "trout"	3	5
Micropterus dolomieu		2	4
Hiodon alosoides	Shad	3	21
Hiodon tergisus		1	22
Aplodinotus grunniens	Fresh water drum, "gaspergou"	3	6
Centrarchus macropterus	Round sunfish	2	60
Ictiobus cyprinella	Common buffalo	2	14
Ictiobus bubalus	Small-mouth buffalo	1	1
Percina caprodes	Log perch	2	2
Amia calva	Bowfin, "grinnel"	2	4
Lepisosteus tristoechus	Alligator-gar	2	6
Labidesthes sicculus	Skipjack	2	5
Stizostedion vitreum		2	5
Elassoma zonatum	Pigmy sunfish	1	75
Fundulus chrysotus	Killifish	1	8
Ictalurus furcatus	Blue cat	1	4
Carpiodes thompsoni		2	2
Carpiodes velifer		2	73
Eupomotis (sp. ?)		1	1
Serranidae (gen. ?, sp. ?)		1	1

A comparison between the numbers of Gambusia in the natural bayou and in all other classes of water shows an average of 25 specimens for each collection in the bayou and an average of 63 per collection for all other places. These figures indicate that these little fish are very abundant and very generally distributed in the region. The larger average per collection for all classes of water, as compared with the natural bayou, is explained by the fact that certain collections were made at the season of low stages of water which found these fish highly concentrated in some locations.

CLEARING THE BAYOU.

The clearing of the bayou was done during August, 1915. It was accomplished then for the reasons that the water in the stream was at its lowest level and that the plantation had finished its cultivation of the crops but had not as yet begun to harvest. This plan gave minimum water conditions and a supply of labor for the work without interference with the plantation operations. The smaller under-

growth was removed first, piled along the banks, and burned when sufficiently dry. The trees, logs, and stumps were then removed and placed upon the banks in suitable lengths for hauling away for use as firewood. In many instances the roots of the larger trees and old snags could not be removed without an amount of effort which would have added greatly to the cost of the work. These were sawed off even with the bed of the bayou and allowed to remain. They might have been removed rather cheaply by the use of dynamite, had the facilities for that work been available. The photographs represented by Plate III, Figure 3; Plate IV; and Plate V, Figure 1, give a very good idea of the extent and nature of the work that was done. The appearance of the stream during the operation of clearing is shown in Plate V, Figures 2 and 3.

CONSTRUCTION OF THE DAM.

In making the fill, or cross levee, for the dam, advantage was taken of a shallow point in the bed of the bayou used as a low-water crossing by the tenants. The banks at this point were favorable—that is, high enough on either side to allow the water to be raised to the required level. The required height of water was gained by running levels along the banks above the site of the dam. The dam was constructed to give a depth of 4 feet 10 inches at the floor of the spillway. When one recalls that the fall in the bed of the bayou in this section averages only 0.6 foot to the mile, it is seen that the level at the dam was carried back over the course of the stream for a considerable distance with only a slight variation in depth. The impounding was effective for depth about ½ mile above the zone included in the survey, with the exception of a ridge which crosses the bed of the bayou just above the last station.

The details of the fill and spillway for the dam are shown in Figure 2 and in Plate VI, Figures 1 and 2. The completed dam, with bridge over the spillway, providing a roadway to the section of the plantation lying on the opposite side of the bayou, is shown in Plate VI, Figure 3. The labor and material involved in clearing the bayou and in the construction of the fill and spillway for the dam, are shown in Table 6. The bill of lumber for the spillway is shown in Figure 2.

TABLE 6.—*Cost of clearing a section of Bayou Walnut and impounding water in same, 1915.*

Preliminary survey, running levels, plan and specifications of spillway		$45.00
Clearing undergrowth and grass from bed and edges of bayou, including piling and burning:		
15 men, 6 days, at $1.25	$112.50	
3 men, 5 days, at $1	15.00	
		127.50

FIG. 1.—Looking up channel of Bayou Walnut, 1,500 yards above site of dam, before clearing.

FIG. 2.—Looking up channel of Bayou Walnut during the work of clearing, from point 300 yards above site of dam.

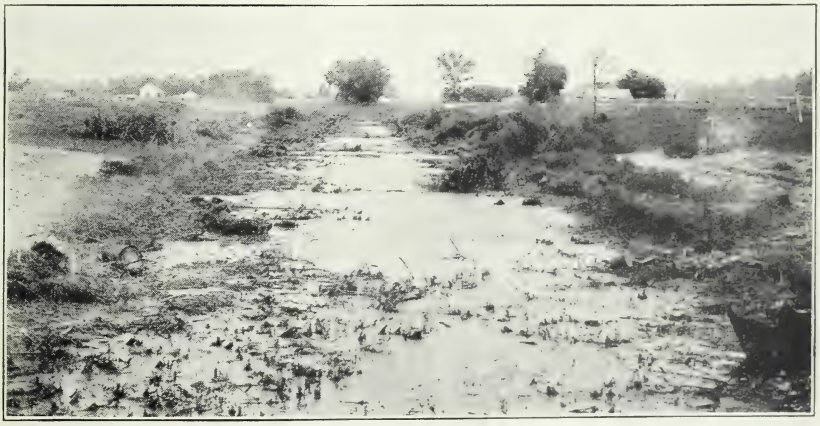


FIG. 3.—Looking up channel of Bayou Walnut from site of dam, after channel has been cleared and undergrowth piled along banks.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

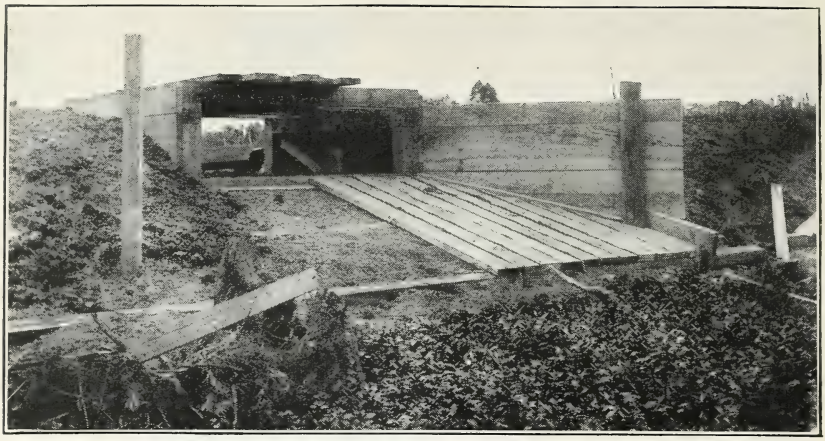


FIG. 1.—View showing construction of spillway-box and downstream apron in dam.

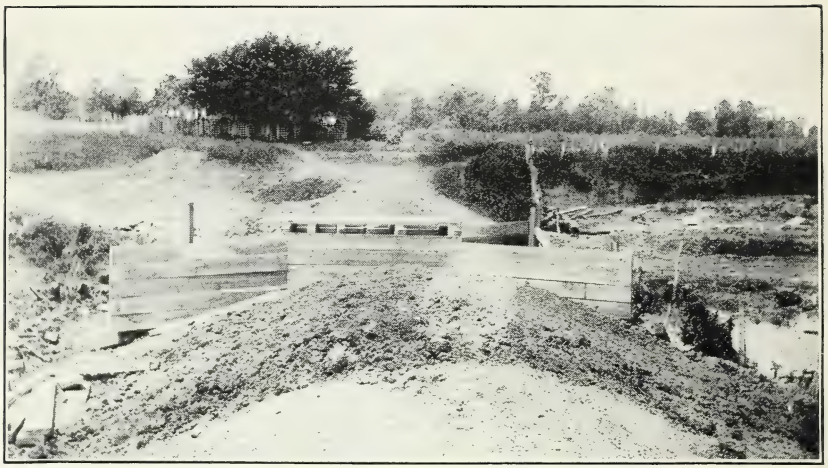


FIG. 2.—View across Bayou Walnut showing wing walls of spillway and bridge over spillway box.

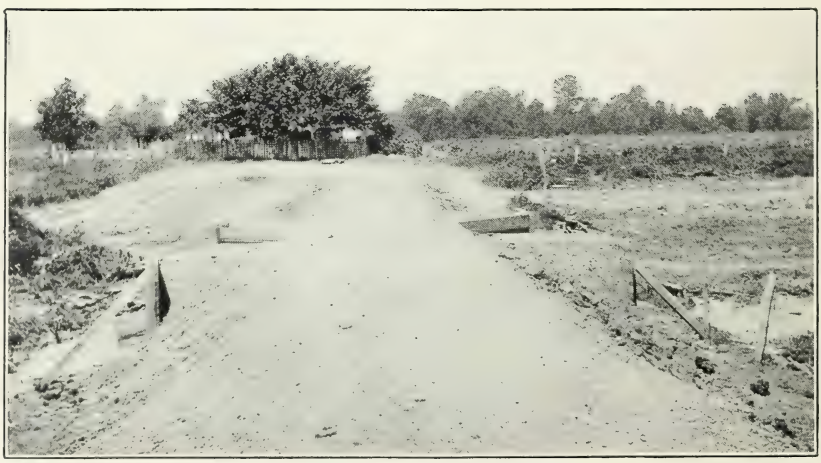
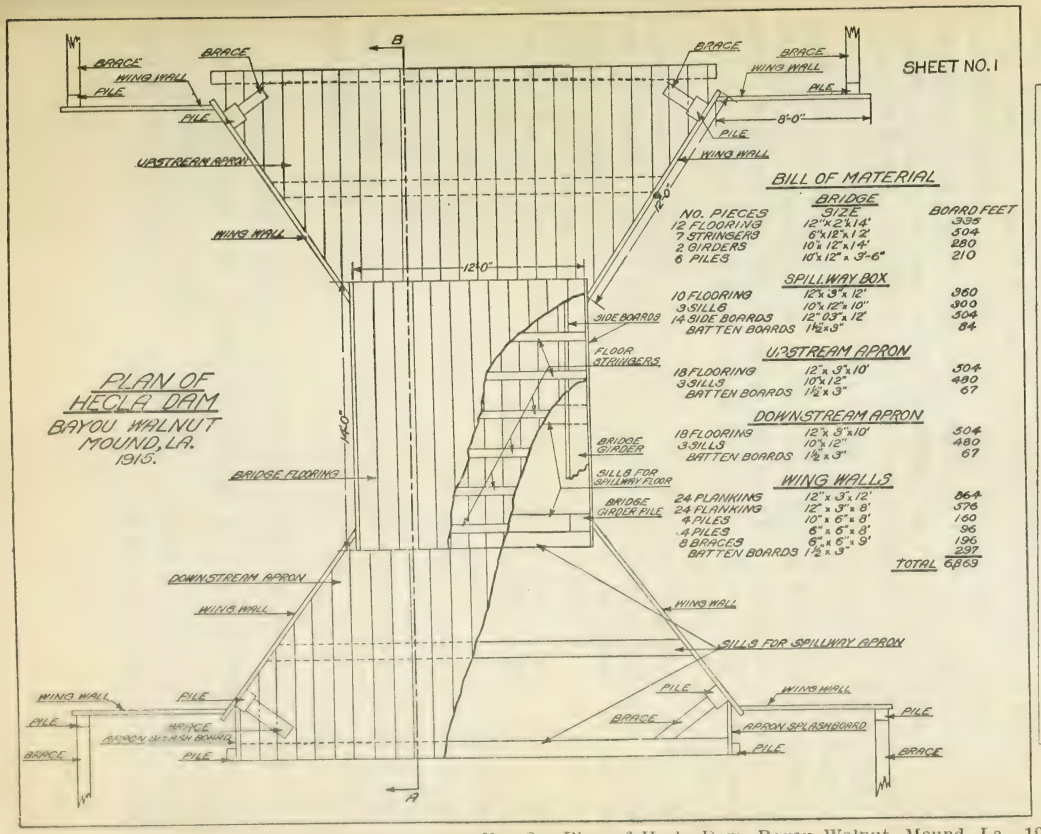


FIG. 3.—View across Bayou Walnut at site of dam, showing roadway to opposite side of bayou.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.


SHEET NO. 1
PLAN OF HECLA DAM
BAYOU WALNUT MOUND, LA.
1915.
BRACE
WING WALL
PILE
UPSTREAM APRON
12'-0"
14'-0"
8'-0"
SIDE BOARDS
FLOOR STRINGERS
BRIDGE GIRDER
BRIDGE FLOORING
SILLS FOR SPILLWAY FLOOR
BRIDGE GIRDER FILE
DOWNSTREAM APRON
SILLS FOR SPILLWAY APRON
APRON SPLASHBOARD
BRIDGE SIDEWALK BOARDS
A
B
BILL OF MATERIAL
BRIDGE
NO. PIECES SIZE BOARD FEET
12 FLOORING 12" x 2" x 14' 336
7 STRINGERS 6" x 12" x 12' 504
2 GIRDERS 10" x 12" x 14' 280
6 PILES 10" x 12" x 3'-6" 210
SPILLWAY BOX
10 FLOORING 12" x 3" x 12' 360
3 SILLS 10" x 12" x 10" 300
14 SIDE BOARDS 12" 03" x 12' 504
BATTEN BOARDS 1½" x 3" 84
UPSTREAM APRON
18 FLOORING 12" x 3" x 10' 504
3 SILLS 10" x 12" 480
BATTEN BOARDS 1½" x 3" 67
DOWNSTREAM APRON
18 FLOORING 12" x 3" x 10' 504
3 SILLS 10" x 12" 480
BATTEN BOARDS 1½" x 3" 67
WING WALLS
24 PLANKINS 12" x 3" x 12' 864
24 PLANKING 12" x 3" x 8' 576
4 PILES 10" x 6" x 8' 160
4 PILES 6" x 6" x 8' 96
8 BRACES 6" x 6" x 9' 196
BATTEN BOARDS 1½" x 3" 297
TOTAL 6,869

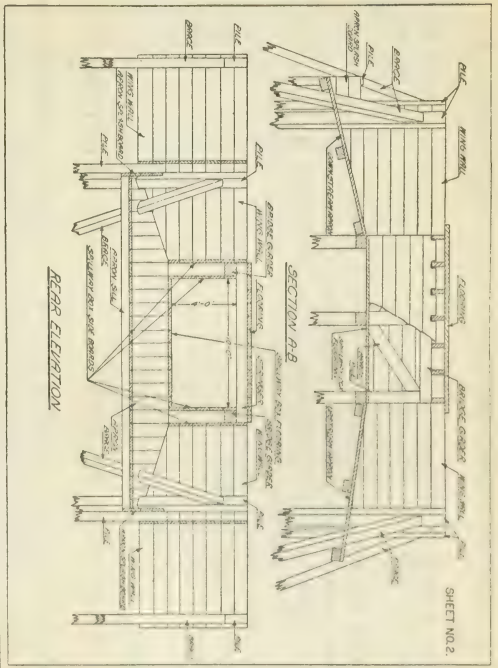


FIG. 2.—Plan of Hecla Dam, Bayou Walnut, Mound, La., 1915.

Removal of trees and stumps and cutting into suitable lengths for hauling away:		
16 men, 8 days, at $1.25	$160.00	
1 team and driver, 4 days, at $3	12.00	
		$172.00
Raking edges and burning trash, 4 men, 6 days, at $1		24.00
Fill or cross levee at dam, 6 teams and drivers, 5 days, at $3		90.00
Lumber for spillway, 7,000 square feet cypress, at $18 per M		126.00
Carpenter work on spillway:		
1 carpenter, 6 days, at $2.25	13.50	
1 helper, 6 days, at $1.50	9.00	
2 helpers, 2 days, at $1	4.00	
		26.50
Total		$611.00

MAINTENANCE WORK FOLLOWING CLEARING AND CONSTRUCTION.

A comparison of the cleared bayou, before the water backed up over the bed, with the natural conditions that have already been shown, may be made from the illustrations in Plate VII and Plate VIII, Figure 1. These views were taken after the undergrowth had been burned and the wood from the trees and logs had been hauled away. Later in the year, at the onset of the winter rains, the water began backing over the bed above the dam. This condition is shown in Plate VIII, Figure 2. It is noted that quite an amount of débris was floated to the surface. As the water level was raised, this floating material collected along the margins, and this was cleaned out with rakes and burned. The appearance of the bayou later in the season, when filled with water, is shown in Plate VIII, Figure 3, and Plate IX, Figure 1.

The only maintenance work, in so far as vegetation is concerned, was the clearing of the "floatage" along the banks following the first rise of water and cutting back a comparatively small amount of second growth, mostly grass (*Zizaniopsis miliacea*) and willow shoots that found their way to the surface of the water the following spring. These shoots were removed by the use of a boat and a curved knife on a long handle. Maintenance work has been required on the dam by reason of the work of crawfish, *Cambarus* sp., about the spillway, and this difficulty, as well as the effect of the work of the crawfish on the water level above the dam, and in turn the effect of the change in water level on the marginal vegetation, will be discussed later.

SURVEY OF ANOPHELES BREEDING AFTER IMPOUNDING.

A comparison of the Anopheles breeding in the impounded area and in the natural bayou is shown by the collections in the general survey work for the years 1916 and 1917. The records for these collections are listed in Table 7.

TABLE 7.—*Collections of Anopheles larvæ, Bayou Walnut, Mound, La., 1916–17.*

Date.	Record No.	Locality.	Water.		Vegetation.	Character of location.	Amount of Shade.	Gambusia present.	Species.
			Depth.	Temp.					
1916.			*Inches.*	°*F.*					
July 26	194	H84			Jussiaea	Channel	Shade	Very abundant	Quadrimaculatus.
Aug. 2	201	H151			Spirogyra	Margin	Open	Common	Do.
2	201	H151			Bushes and floatage.	Channel	Shade	....do	Do.
8	205	H151			Spirogyra	Margin	Open	....do	Do.
8	205	H151		86	Grass and floatage.	Channel	Part shade	....do	Do.
8	205	H153	36	86	Willow	....do	Shade	....do	Do.
1917.									
June 11	1683	300 yards below dam	3–10	76	Shrubs	Margin	....do	....do	Do.
11	1684	....do	8	77	....do	....do	Part shade	....do	Do.
11	1685	U. S. B. F. Station 2	12	88	....do	....do	Open	....do	Do.
26	1699	U. S. B. F. Station 1	6	77	....do	....do	Part shade	....do	Species undetermined.
26	1700	....do	6	77	Duckweed	....do	Open	....do	Quadrimaculatus.
July 5	1904	U. S. B. F Station 5		94	Grass	....do	Part shade	....do	Do.
14	B17	H153	6–12	79	Willow and floatage.	....do	Shade	....do	Do.
14	B18	U. S. B. F. Station 2		91	Duckweed	....do	Open	Abundant	Species undetermined.
23	B23	H153	15–18	90	Floatage	Channel	Shade	Common	Quadrimaculatus.
26	B33	U. S. B. F. Station 1		96	Duckweed	Margin	Open	....do	Do.
26	B34	H153	15–18	88	Willow	....do	Shade	....do	Species undetermined.
Aug. 1	B37	U. S. B. F. Station 1	6–8	86	Buttonbush and willow.	....do	....do	....do	Quadrimaculatus.
3	B40	H153	15	81	Willow	Channel	....do	....do	Do.
9	B44	H153	9	84	....do	....do	....do	Abundant	Species undetermined.
11	B47	U. S. B. F. Station 1	6–8	79	Duckweed	....do	....do	....do	Do.

It is seen that the collections are confined to the sections of the bayou below the dam and to the backwater above the impounded zone. No specimens were taken in the collections in the impounded area proper. The section of the bayou above the impounded area was clear for a distance of about ½ mile and the backwater gave favorable conditions for nonbreeding in this distance with the exception of a limited area just above the last station where a ridge crosses the bed of the bayou and where the aquatic grass (*Zizaniopsis miliacea*) persisted, as shown in Plate IX, Figure 2. The maximum depth where this grass survived was about 1 foot. Below this point to the dam, a distance of nearly a mile, an average depth of 3½ feet was maintained which was sufficient to suppress this grass as well as all other vegetation in the channel. Another location of Anopheles breeding found above the impounded zone was some distance above the growth of grass mentioned, among willows and other vegetation characteristic of natural bayou conditions. This location is shown in Plate IX, Figure 3.

FISHES IN THE IMPOUNDED AREA.

A survey of the fishes in the impounded area in Bayou Walnut, the results of which are given in Table 8, shows that the top minnow (*Gambusia affinis*) finds no difficulty in establishing itself under the conditions of deeper and open water. The fish collections in this water also show that the larger fishes of the region, those of value for food, have found their way to the impounded area in some numbers. The more valuable of these for food are the crappie or "white-perch" (*Pomoxis annularis*), the calico bass (*Pomoxis sparoides*), the large-mouth black-bass or "trout" (*Micropterus salmoides*), and the warmouth bass or "goggle-eye" (*Chaenobryttus gulosus*). These game fishes are largely predacious and of course take their toll from the Gambusia, but this feeding of these larger fishes upon the little top minnows must not be viewed so much in the light of the reduction of the mosquito-eating minnows as from the standpoint that the patrol work which they do serves to keep the little fishes in the shallow water along the margins. In the open water of the impounded area there is no mosquito breeding and since the salvation of the little fishes depends upon their remaining along the margin to escape the larger fishes, the value of the larger fishes as an indirect aid in mosquito control is seen.

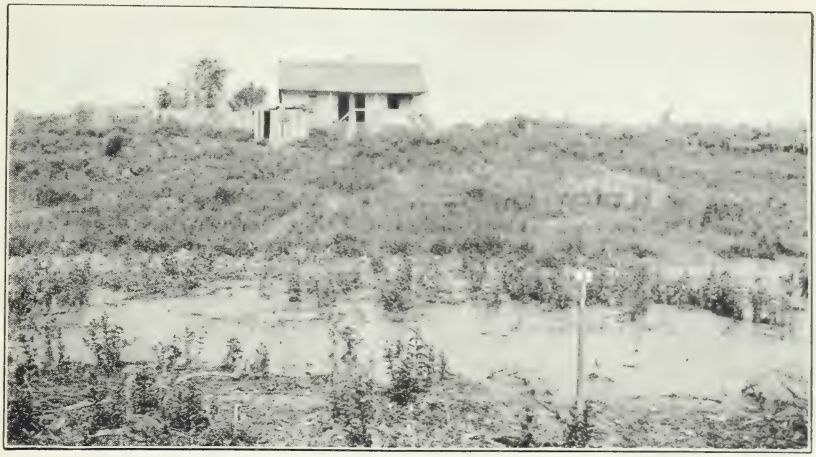


FIG. 1.—View across Bayou Walnut, after clearing, 200 yards above site of dam. Compare with Plate III, Figure 3.

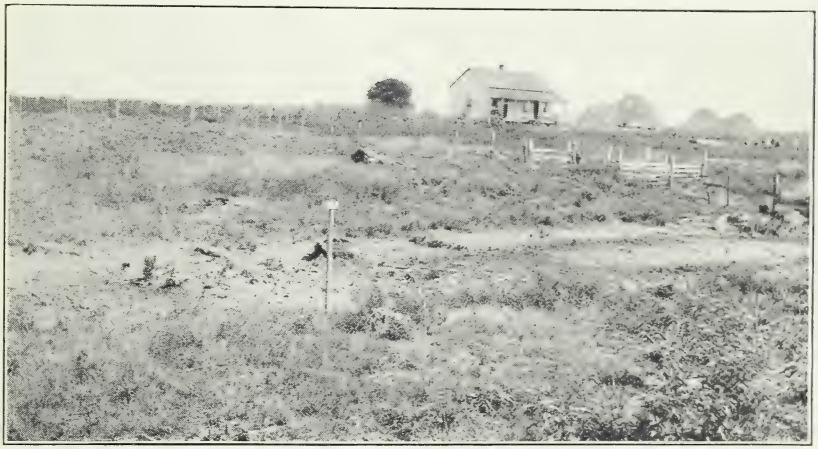


FIG. 2.—View across Bayou Walnut, after clearing, 300 yards above site of dam. Compare with Plate IV, Figure 1.

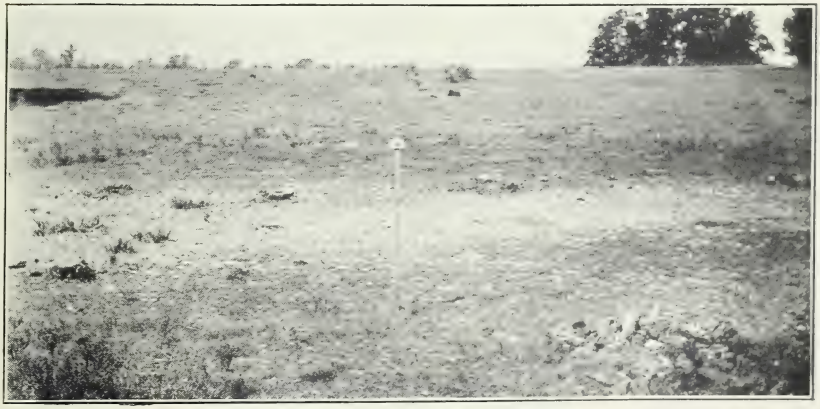


FIG. 3.—View across Bayou Walnut, after clearing, 800 yards above site of dam.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

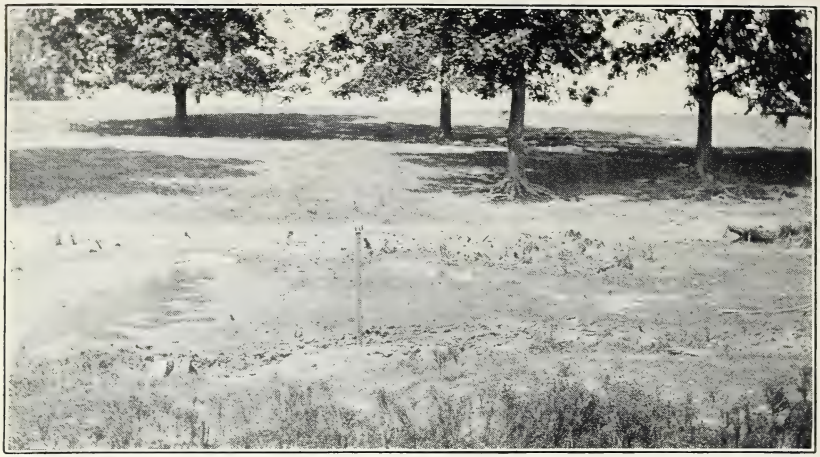


FIG. 1.—View across Bayou Walnut, after clearing, 1,000 yards above site of dam.

FIG. 2.—Looking up channel of Bayou Walnut, after first rise of water, from point 300 yards above site of dam. Note "floatage" along margin. Compare with Plate IV, Figure 1, and Plate V, Figure 2.

FIG. 3.—View above dam, Bayou Walnut, with bayou filled with water. Compare with Plate V, Figure 3.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

FIG. 1.—View toward dam and spillway, Bayou Walnut, from upstream, showing bayou filled with water.

FIG. 2.—View across Bayou Walnut, showing aquatic grass, *Zizaniopsis miliacea*, in bed of bayou, above impounded zone.

FIG. 3.—View along margin of Bayou Walnut, above impounded zone, showing natural bayou conditions.

IMPOUNDING WATER TO CONTROL MALARIA MOSQUITOES.

TABLE 8.—*List of fishes taken in 12 collections in the impounded area, Bayou Walnut, Mound, La., 1916–17, by F. M. Barnes, U. S. Bureau of Fisheries.*

Species.	Common name.	Number of collections.	Number of specimens.
Gambusia affinis	Top minnow	7	163
Lepomis cyanellus	Green sunfish	7	95
Lepomis humilis	Sunfish	6	89
Lepomis pallidus	Blue-gill sunfish	1	1
Lepomis ischyrus	Sunfish	1	1
Lepomis symmetricus	do	1	1
Lepomis megalotis	do	1	1
Pomoxis annularis	Crappie	5	103
Pomoxis sparoides	Calico bass	3	25
Ameiurus nebulosus	Common bullhead	5	43
Dorosoma cepedianum	Hickory shad	5	15
Notemigonus crysoleucas	Roach, shiner	3	151
Aphredoderus sayanus	Pirate perch	2	3
Micropterus salmoides	Large-mouth black bass	2	2
Micropterus dolomieu		1	3
Chaenobryttus gulosus	Warmouth bass, "goggle-eye"	1	12

In the comparison of the numbers of the top minnows found per collection in the natural bayou and in all other classes of surface water it was seen that for all classes of water there was an average of 63 Gambusia per collection and for the natural bayou 25 specimens per collection. From the figures in Table 8 we find an average of 14 specimens of Gambusia for the 12 collections made in the impounded water. Just as the comparison of the numbers of these fish in the natural bayou and in all other classes of water is influenced by the fact that some of the collections in the latter case were made in locations where the fishes were highly concentrated, so in the impounded water, as compared with the natural bayou, we must consider the effect of great dilution in the former. It is sufficient for the practical results of the work to note that the Gambusia survived in important numbers the effects of the impounding, and that the presence of the game fishes in the area serves the purpose of keeping the top minnows along the margins where they are useful in the marginal control of mosquito breeding.

FACTORS PREVENTING MOSQUITO BREEDING IN THE IMPOUNDED WATER.

The nonbreeding of Anopheles in the impounded water is due to a number of factors which have not as yet been definitely measured. In general, as has been stated, the important difference between the impounded section of the bayou and the natural bayou is just the difference between lakelike conditions which do not favor the development of Anopheles and swamplike conditions which do favor such development. The factors which are considered to operate against mosquito development are the greater freedom for action on the part of the predators, the fish and the aquatic insects; wave action; depth, which influences temperature of the water; absence

of the vegetable shelter, which operates against the concentration of adults along the bayou and consequent oviposition; and depletion of the larval food of Anopheles furnished by the decaying vegetation and the low forms of aquatic life, both plant and animal, common to the swamplike conditions of the natural bayou.

LEAKAGES CAUSED BY CRAWFISH AND MEANS OF PREVENTING THEM.

The work of maintenance at the dam due to the action of crawfish about the boxing of the spillway has been mentioned. The crawfish burrowed through the fill below the level of the water above the dam to the lower side of the fill. The action of the water through these openings in carrying away the dirt caused serious leakage, which resulted in a decidedly lower level of water above the dam. In several instances the level of the bayou was lowered materially before proper repairs in the dam were made. This damage was not serious the first year following the completion of the dam, but during the following years, up to 1920, considerable expense was involved in preventing the leakage in the dam due to the work of the crawfish. In 1920, a double course of sheet piling with overlapping joints was driven below the fill, leaving an opening for the spillway, the boxing of which was carried through and over the sheet piling. This served to prevent the crawfish from working to the outside, below the fill, and to hold the water above the dam at a permanent level.

An important biological observation was made in connection with the variable water level caused by the leakage in the dam due to the crawfish. It was found that when the water was lowered, after remaining at one level for a period, the water found a clean edge free from débris and grass and, further, that the drying out above the new level served to destroy the aquatic and semiaquatic vegetation that had gained a foothold. Then when the leakage had been repaired and the water level raised to its original height, it rested against comparatively clean margins. The growth of marginal vegetation was thus discouraged by this variable water level, and this explains the lack of any maintenance work on control of marginal vegetation in the impounded area. Thus, the expense in the maintenance work on the dam was offset in part by the saving in the work on the margins.

The experience with the crawfish suggests two improvements to be considered in any further work on impounding water in a bayou in this region. The first is the prevention of injury to the fill in the dam on the part of crawfish. This can be accomplished by a core wall extending below and to each side of the spillway box in the center of the fill. The second is provision for controlling the water level above the dam. The object of this is to make use of the effect

of a variable water level on marginal vegetation and marginal breeding. This is obtained by a change in the water level from time to time. This can be accomplished by a sluiceway through the fill below the level of the floor of the spillway. The flow of water through the sluiceway can be controlled by a gate. If the sluiceway is placed at the level of the bed of the bayou, in the center of the fill, it will act efficiently in lowering or raising the water level above the dam, and, also, the current of water through the sluiceway at this point will flush out and carry away the mud and sediment that tend to accumulate in the bed immediately back of the fill.

ADVANTAGES OF IMPOUNDING, APART FROM PREVENTION OF ANOPHELES BREEDING.

A special advantage to the plantation, apart from the control of Anopheles breeding in the bayou, is the fact that the impounded water gives an ample supply of good water for the live stock throughout the dry summer season. The land lying between the roadway and the bed of the bayou is ordinarily used for pasture purposes by the tenants living along the stream. Except in some instances where clearing has been done in a comparatively wide strip of land found between the road and the channel of the bayou, the pasture along the stream is limited in extent and the grasses are crowded out by weeds, bushes, trees, and vines. During the seasons of dry weather the water in the natural bayou is shallow and stagnant. The supply is often difficult of access by reason of the tangle of overhanging and aquatic vegetation. The animals often become bogged in seeking the water, and the more shallow and isolated pools are converted into wallows, particularly where hogs are pastured along the bayou side. The situation under these conditions is unsightly and insanitary and the supply of water is limited in amount and of the poorest quality. With the limited pasturage the animals do not thrive, and often die. The pasture for the plantation stock—that not owned by the tenants—is the wet land lying between the cultivated areas and the timber and swamp. These pasture lands extend into the timber and the live stock depend upon the swamps and the shallow lakes in the basins of same for water. In any prolonged dry season this supply becomes greatly restricted and as objectionable in quality as that in the bayou. When this situation becomes acute it is necessary for the plantation to drive wells throughout the pasture areas and pump water. This adds greatly to the expense of taking care of the stock. On Hecla plantation, following the clearing of the section in Bayou Walnut and impounding the water, the management not only extended the fencing to include the entire impounded area, but also arranged the fencing of the pastures in one section of the plantation so that by a system of gates the live stock

from the regular pastures could visit the impounded water. The impounding was effective for depth, in so far as an abundant and good water supply is concerned, for a distance of nearly 2 miles and thus furnished water for all of the stock of the tenants living along the stream and for the larger portion of the plantation live stock during the dry seasons as well. The clearing served to increase the amount of available pasture, particularly of value to the tenants for their cows and work animals, and the feeding of these animals along the impounded water aided in the suppression of the marginal vegetation. The management of the plantation has stated that the advantage of a permanent supply of good water for the live stock would alone justify the expense of the clearing and the impounding project.

The owners of Hecla plantation are also operating a lumber mill at Mound. Before impounding the water in Bayou Walnut, the source of water for the boilers at the mill was a driven well. This water proved undesirable for boiler purposes by reason of the salts which were precipitated in the generation of steam. This caused some expense and considerable loss in time at the mill. A pipe line was laid from the bayou to the mill and the impounded water pumped to same for boiler purposes. The management of the mill has stated that the saving in the mill expenses would more than justify an annual expense equal to the cost of the project. In fact, the mill management contributed very largely the funds for maintenance at the dam made necessary by the injury from the crawfish.

A further advantage is gained in that the impounded water offers a source of fish for food. The bass, or "trout," and the crappie, or "white perch," are now present in some numbers. The "buffalo" (*Ictiobus cyprinella*) has been caught occasionally and will no doubt increase in numbers, and the sunfish (*Lepomis* spp.), or "bream," are common. The tenants are able to do a considerable amount of line fishing and every catch adds to the supply for their tables, furnishing a valuable food and a saving in meat.

An advantage not to be overlooked is the great improvement in the property which adds to its value. The further value of the impounded area of the bayou as a place of recreation for the tenants is a very practical point in plantation economy which should be given consideration.

SUMMARY.

The bayous, or streams, of the Delta region flow away from the river, their banks are higher than the surrounding lands, and the fall in their beds is very slight. The shallowness of water in these streams, with prevalent aquatic and overhanging vegetation, favors the development of Anopheles mosquitoes. The peculiar relation

of these streams to the surrounding topography does not permit drainage. In the absence of a drainage outlet, the Bureau of Entomology conceived the idea of clearing a section of one of the bayous and impounding the water to note the effect of a change from the swamplike conditions of the natural bayou to the lakelike conditions of the impounded area, on the capacity of the bayou for Anopheles production.

It is important to control breeding of Anopheles in bayous for the reason that these streams offer a near-by source of mosquitoes, since the houses on a plantation in the Delta are located on the roadways along the bayou banks, where one of these streams sections or bounds a property.

A section of Bayou Walnut at Mound, La., was cleared of all vegetation and the water in this area impounded by means of a cross-levee, or fill, and spillway. This served to keep the water over the bed of the stream above the dam at a sufficient height to suppress the further growth of vegetation.

It was found by comparative studies that this clearing and impounding was effective in preventing the breeding of Anopheles in the bayou where formerly such breeding was common.

Cooperative work on the part of the United States Bureau of Fisheries demonstrated that the mosquito-eating top minnow (*Gambusia affinis*) is generally distributed in the region, but that under natural delta conditions this minnow is found coincident with prevalent breeding of Anopheles. It was also demonstrated that this minnow has established itself in important numbers along the margins of the impounded area. One of the important factors in the natural control found to exist in the impounded water is believed to be the greater freedom for action which the condition of an open surface of water gives to these fish and to aquatic predacious insects. The fish are noneffective in control under natural conditions by reason of the protection afforded the mosquito larvæ by the aquatic and marginal vegetation and the vegetable débris upon the surface of the water. Other factors in the natural control in the impounded zone are considered to be wave action, influence of a greater depth on breeding, absence of shelter for adults along the course and consequent reduction of oviposition, and the depletion of the food of Anopheles larvæ.

The important points to be considered in impounding water in a bayou for mosquito control are the preliminary clearing of all vegetation, the provision for a permanent level of water sufficiently high to suppress the further growth of aquatic and semiaquatic vegetation, and the maintenance of a clean margin.

A further point in the construction of the dam is provision to prevent the work of crawfish, which, otherwise, work through the fill and cause serious leakage. The water level in the project under dis-

cussion varied greatly at times, due to failure to make such provision. However, from this variable level which occurred, the experience was gained that such fluctuation in level operated as an aid in the control of the marginal vegetation which otherwise would have gained a foothold and would have required an expenditure for the maintenance of clean margins. The suggestions are made that the crawfish injury can be prevented by a core wall through the center of the fill to either side and below the box of the spillway in the dam, and that a variable water level can be secured by a sluiceway, with control gate, through the fill and core wall.

Advantages to the plantation from the impounding work, apart from the control of Anopheles breeding, are a permanent supply of good water for live stock during the dry season; an extension of the land available for pasture; the deeper and more extensive water of the impounded area, which offers a favorable place for game fish and thus furnishes a source of food; and the lake-like body of water which offers recreation to the plantation people and adds to the attractiveness and value of the property.

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